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Title: High throughput tensile testing using femtosecond laser fabrication technique

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Los Alamos NATIONAL LABORATORY

High throughput tensile testing using femtosecond laser fabrication technique

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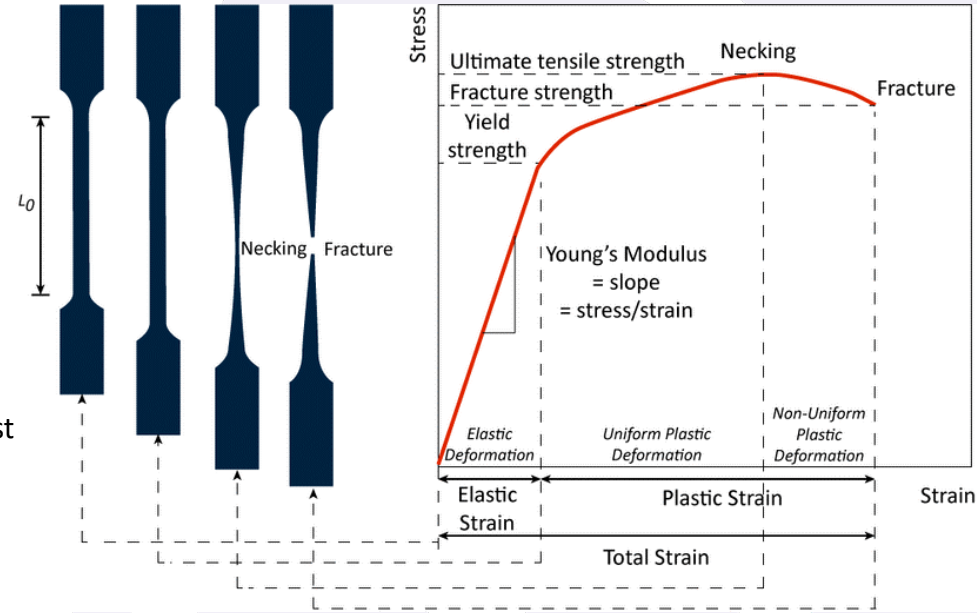
Main Purpose

To demonstrate that a high throughput method for fabrication and mechanical testing produces local and bulk-like results.

Introduction

Mechanical Testing

- Used to determine mechanical properties of a desired material
- Common tests: **Tensile**, Hardness, Fatigue, Creep, etc.
- Tensile tests are used to characterize stress and strain when loaded to failure
- An in-house developed mechanical stage is used to test the samples in tension.



[21] - Ridwan, Ridwan & Prabowo, Aditya & Muhayat, Nurul & Putranto, Teguh & Sohn, Jung-Min. (2020). 7. 188-198.

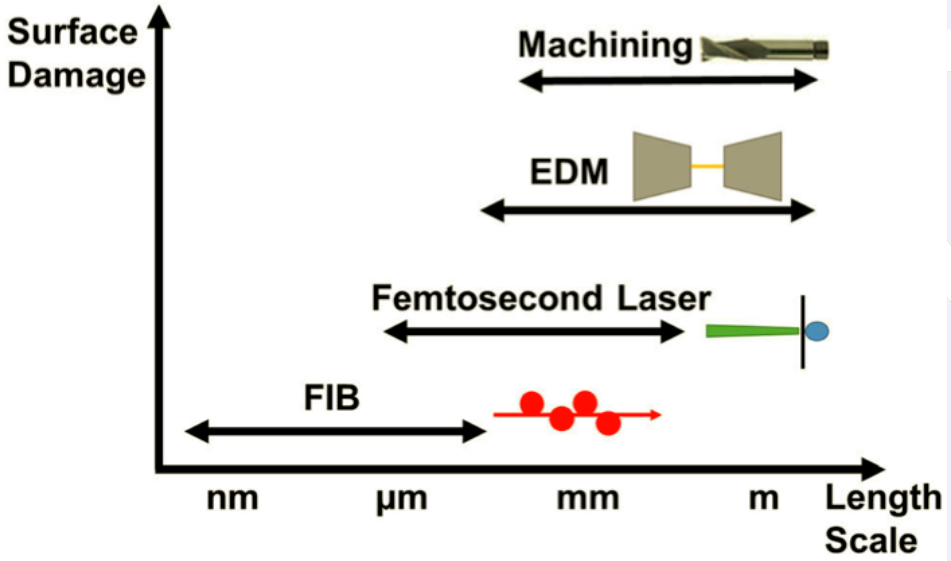
Introduction

Sample Preparation Method

Step 1: Initial grinding/polishing to remove surface impurities and scratches

Step 2: Subtractive fabrication method (Machining, Wire EDM, Laser ablation, and Focused Ion Beam ablation)

→ FIB is time consuming and Machining/Wire EDM cause significant damage at the desired scale (µm to mm)



[7] - Q. McCulloch, J.G. Gigax, P. Hosemann, JOM 72 (2020) 1694-1702.

Introduction

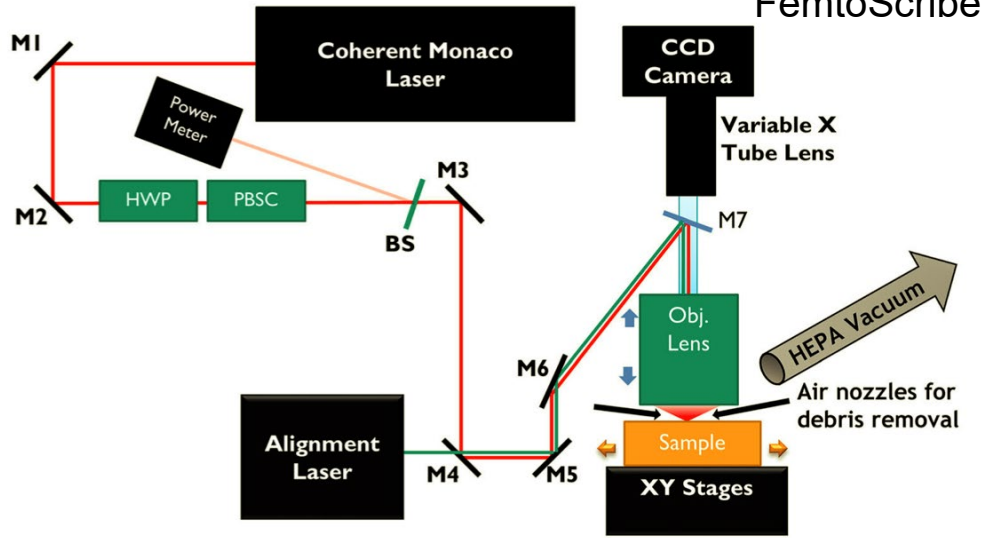
What are femtosecond lasers?

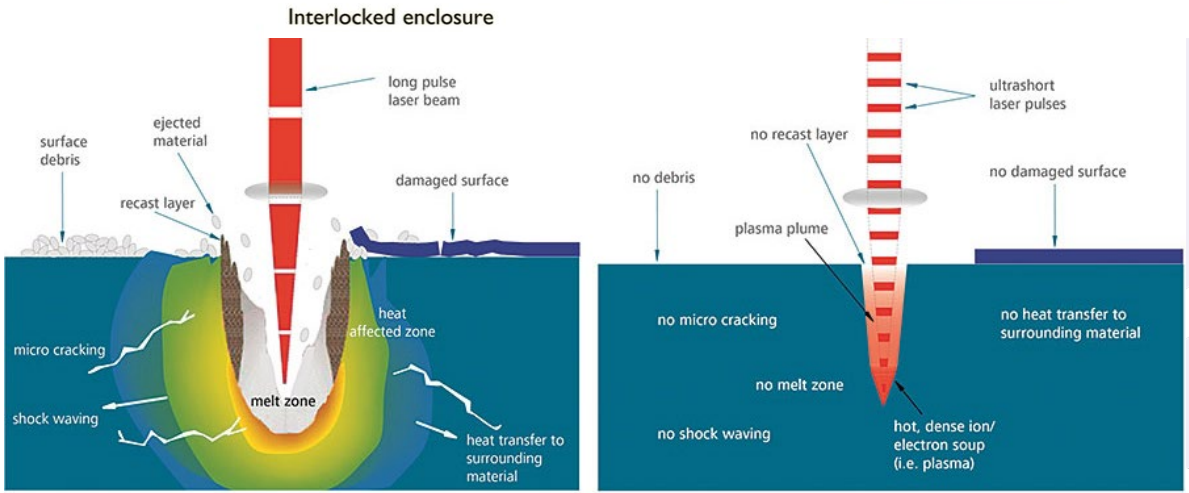
Pulses with magnitude of 350 fs

Produces low heat affected zone (HAZ)

Efficient subtractive machining times for small (sub millimeter) features.

Flexible environments for ablation (in vacuum, water, etc.)





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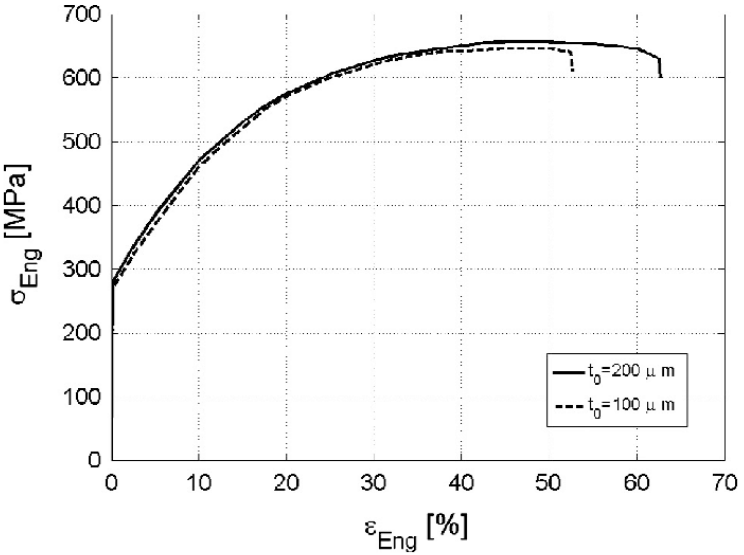
Introduction

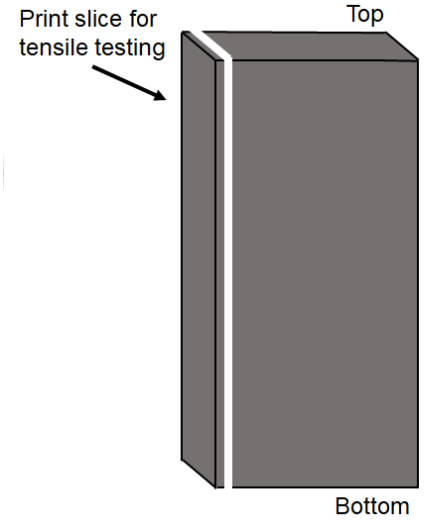
Grade 316L Stainless Steel

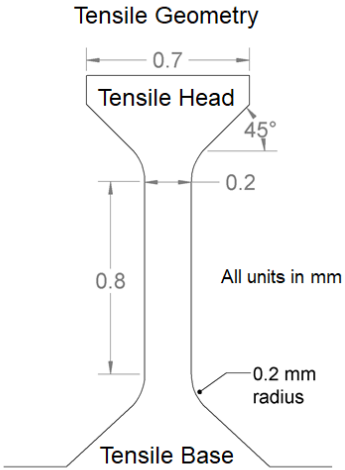
- Used to benchmark the system
- Large material database



Additively Manufactured Grade 91 Steel (AM91)

- Complex microstructure contains fine- and course- grained regions that impact strength and ductility
- Wrought material is a candidate for fuel cladding





[1] - Cayla Harvey, Avery J. Torrez, Sebastian Lam, Hyosim Kim, Stuart A. Maloy, Jonathan Gigax,, Submitted to JOM (2021).

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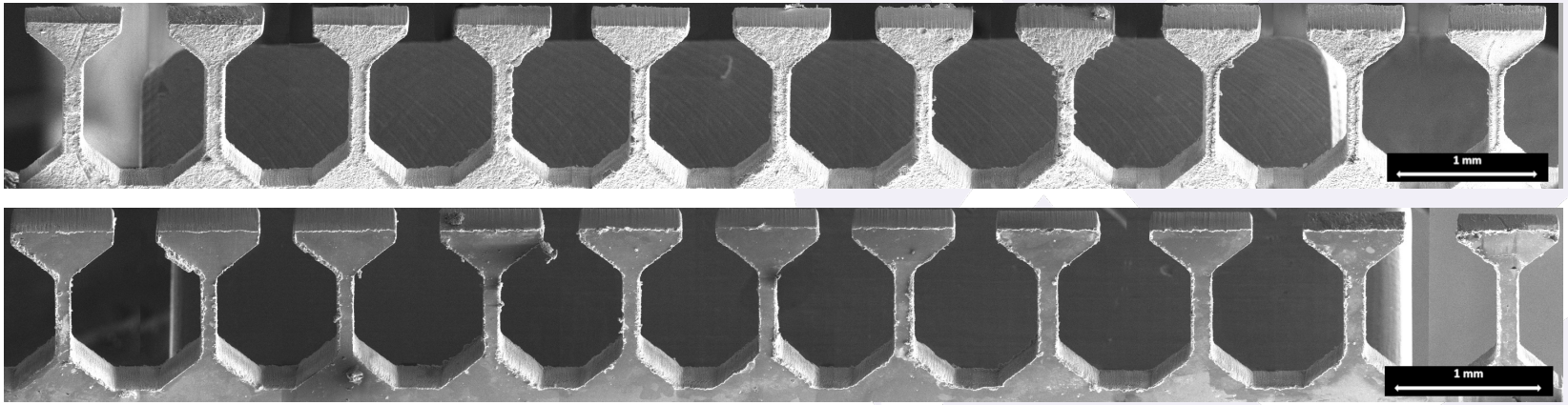
Results

Laser Fabricated Tensile Bars

- Clean and accurate tensile bar cuts
- Slight debris with no visible HAZ
- Cross-sectional area of 0.015-0.020 mm

* This set of 11 took 35 minutes to fabricate (3:11 per sample)



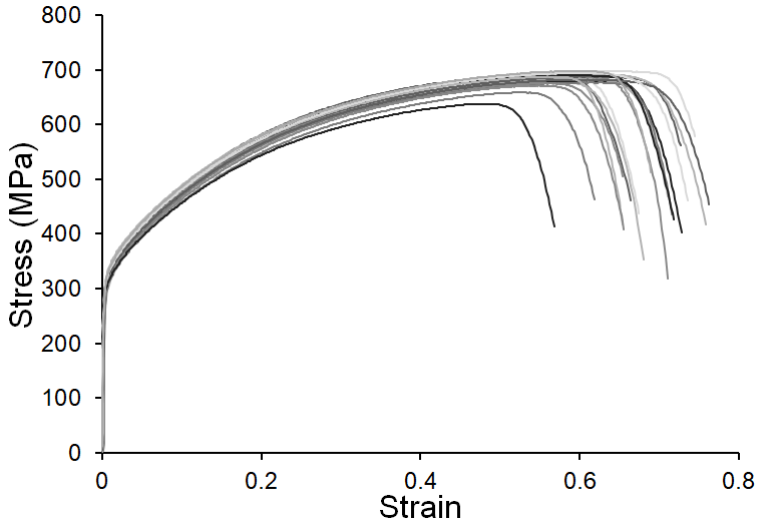
1] - Cayla Harvey, Avery J. Torrez, Sebastian Lam, Hyosim Kim, Stuart A. Maloy, Jonathan Gigax,, Submitted to JOM (2021).

*Only includes time from the start of laser fabrication to the end of tensile test (2E-3 1/s strain rate)

Results

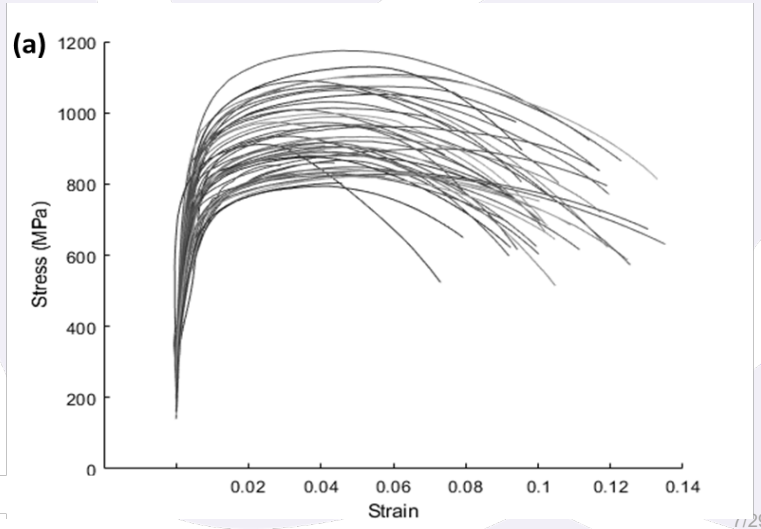
316L Results

- 19 Samples tested @ room temperature
- Time per sample: 5 minutes*
- Little variance to bulk 316L results



AM91 Results

- 66 Samples tested @ room temperature
- Time per sample: 5 minutes*
- More variation in stress-strain response



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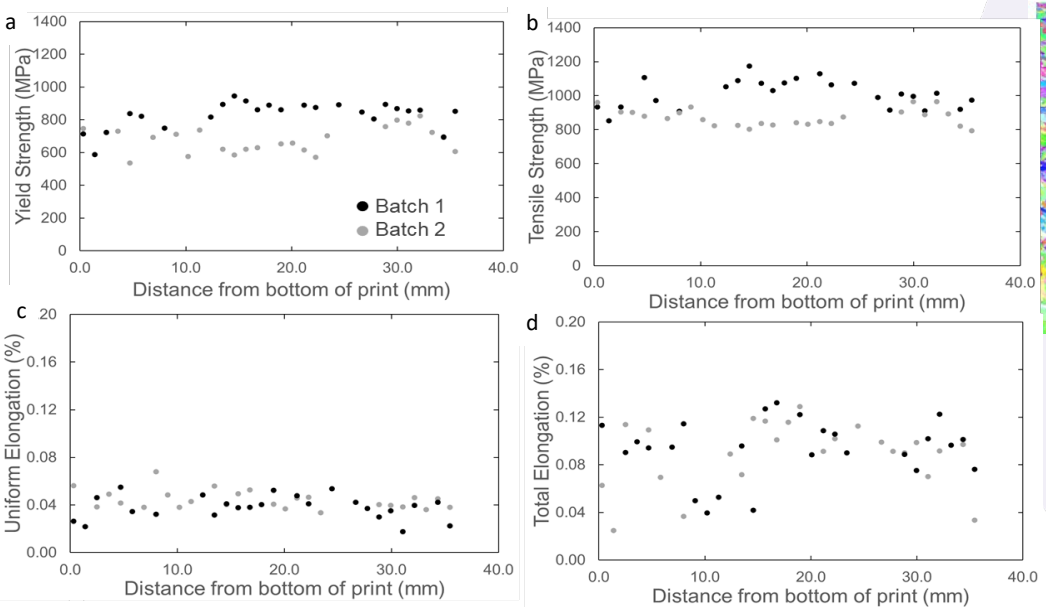
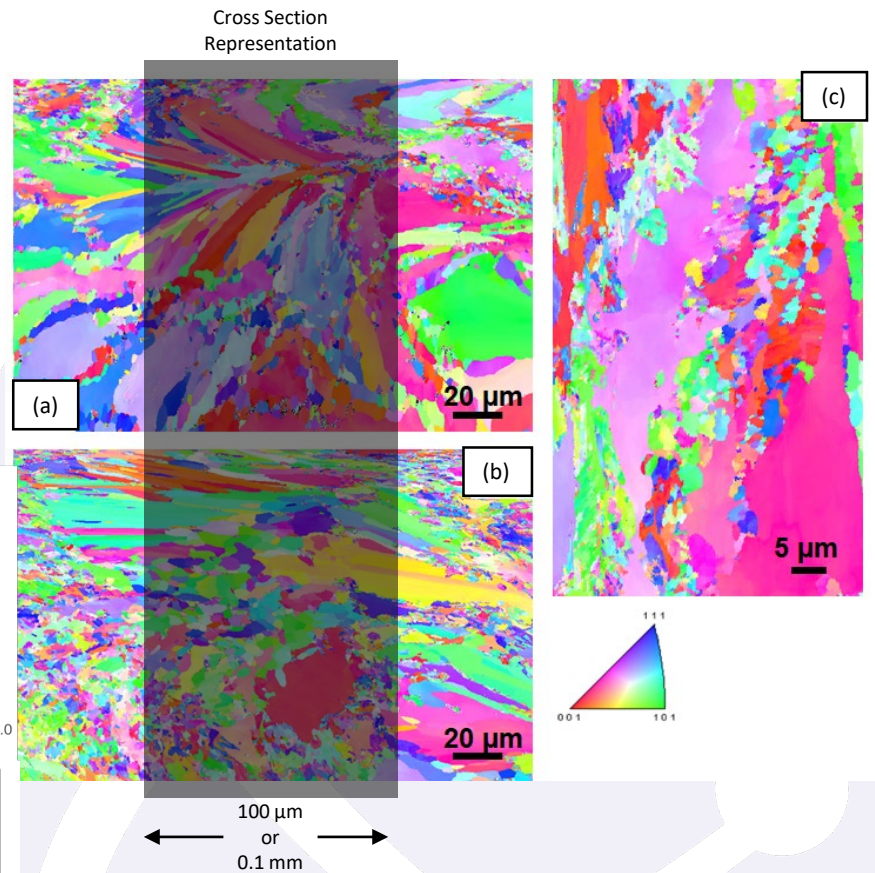
Discussion

Microstructure of AM91

- Grain sizes of >40µm to <1µm
- Variations in microstructure lead to variations in stress-strain responses along various print regions





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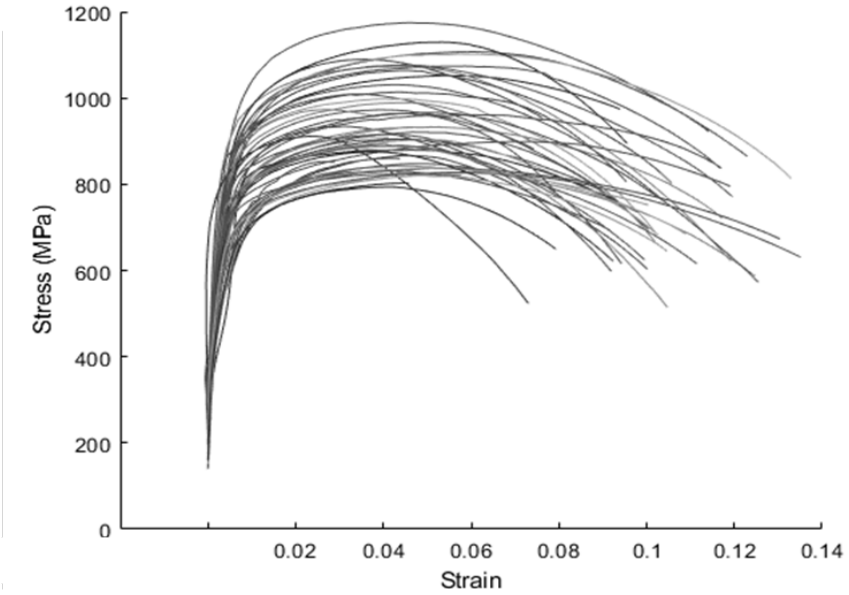
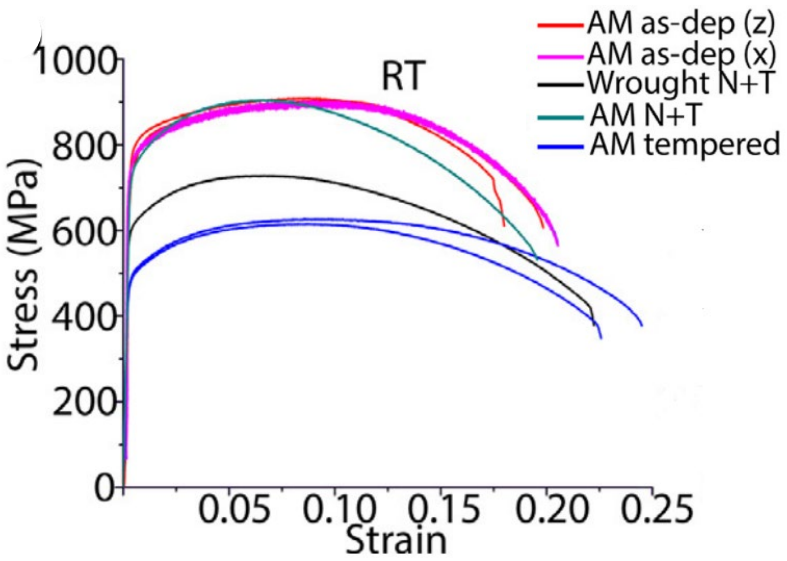
Sub-microscale vs. Bulk Results for AM91

Sub-microscale AM91



Bulk AM91



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Conclusion

- Proves to decrease overall fabrication and testing time significantly and allowed for a large volume of data to be collected effortlessly
- Provides accurate stress-strain responses with homogenous microstructures like 316L.
- Provides boundary limits for strength and ductility for complex heterogeneous microstructures like AM91.

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